Indirect Water Heater Mixing and Control

Not too hot or too cold: water temperature that is just right

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In this, the fourth and final installment in this series on indirect water heaters, commissioning is supposed to be the topic. However, as with so much equipment, good commissioning happens during equipment selection and installation. This article will focus on some final aspects of device installation—wiring and mixing—which, if done correctly, will lead to long and trouble-free use.

CONTROL WIRING

Many factory-built heating system controls, such as outdoor reset controls, use an aquastat or temperature sensor in an indirect water heater to signal the control to turn on the pump and to send hot boiler water through the coil; to turn on the fire in the boiler, if necessary, and to turn off the pump to the heating system to prioritize the making of hot water. Better controls include a feature that turns the heat back on if the demand for hot water has not been met for a certain time. This is to prevent freezing of the building if a real or imagined call for hot water goes unanswered for a long time. If a factory-made control with these capabilities is being installed, which is a good idea, it should also be used to control the indirect water heater because it is cheaper and more likely to work than attempting to field wire these features into a system, and can save energy because of fancy logic built into some controls.

Installations that do not use a factory-built control should use one aquastat in the tank. A second aquastat should be installed in steam boilers and large hot-water-heating boilers and set at somewhere between 150 and 180 F. The lower the temperature, the better because of reduced standby losses, but the lower limit is determined on each installation by the coil's heat-transfer capacity and the hot water demand. Oversizing a tank can allow for a lower aquastat setting, which will reduce standby losses, which is another reason to oversize a tank.

Direct-vent, sealed combustion boilers can start from cold and warm up fast enough to meet a call for hot water, so they should not be wired to stay warm. Instead, the aquastat in the tank should be wired to a relay that turns on both the pump and the boiler, with the relay providing isolation against the heating system control turning on the pump

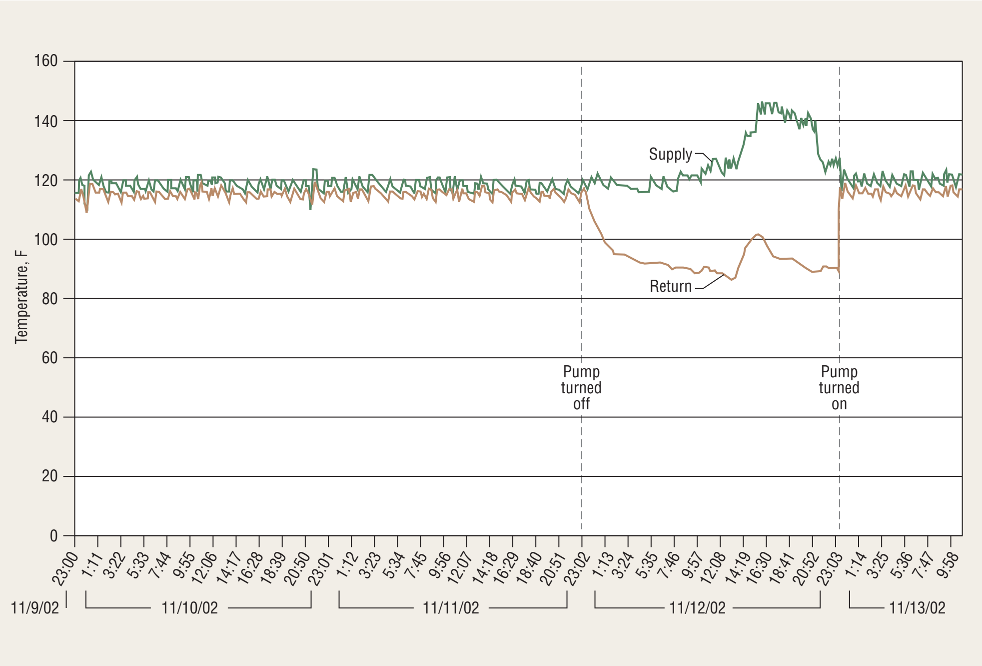

FIGURE 1. This building has an indirect water heater with an insulated ½-in. copper "fake" return piped back from the other end of the basement and a very small pump running nonstop. Just for a test, the return line pump was shut off at 11 pm and turned back on, after many complaints from tenants, nearly 24 hours later. The contrast between delivered temperature accuracy with and without the return line pump running is dramatic.

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whenever the boiler goes on. This arrangement, which fancy electronic controls can be set up to do, is called “cold start” and can reduce standby losses to a bare minimum.

Wiring a chimney-vented boiler for cold start is problematic because when the boiler gets cold, the chimney will get cold and stop pulling and maybe backdraft on startup. Therefore gravity (chimney) vented boilers should not be wired for cold start unless another combustion appliance is keeping the chimney warm.

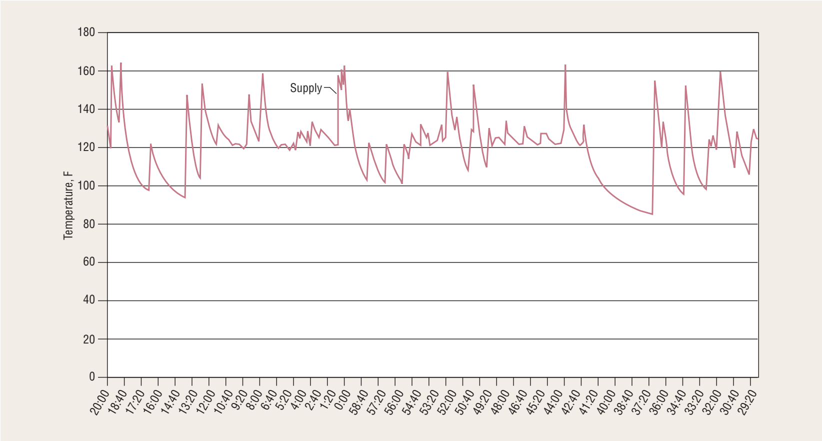

FIGURE 2. In this building, the plumber insisted that the newly installed indirect water heater did not need a return line, claiming that the indirect water heater in his building was absent a return line with no resulting temperature control problems. In reality, the temperature at the hot outlet is sometimes close to the setpoint of 120 F, but it is dangerously overheated at other times.

TO RETURN OR NOT TO RETURN

Some buildings are equipped with return lines that circulate hot water from the top of a faraway hot water riser back to where the hot water is made. Hotels and multifamily buildings usually have return lines from each hot water riser, while many single family houses have no return lines.

The only purpose usually associated with having a return line is to make hot water available soon after someone opens a hot water tap, but as seen in Figures 1 and 2, it is difficult to control the temperature of the hot water without a return line.

Old buildings had return lines that depended on convection to move the water. The water going up hot from the basement was hotter than the water in the return line because heat was conducted and radiated from the pipe to the surrounding air and to branch piping. Hot water is lighter than cool water so gravity moved the water up the supply risers and down the return risers. Despite the utter reliability of gravity, convection could not always be depended on to move the water.

When someone draws hot water from a tap, the flow in the hot water piping increases enough to create a significant pressure drop in the hot-water supply piping. The pressure drop caused by friction in the supply piping can cause the pressure at the top of the return line to be higher than that at the top of the supply pipe. A check valve on each return line branch prevents backflow of cold water back into the hot supply pipe, while flow in the return line stops.

After the hot water faucet is closed, gravity might and might not be enough to start the flow through the return line. An air pocket at the top of a riser or dirt in a check valve might offer more resistance than gravity can overcome. A pump is a much more reliable way of starting the flow and keeping it going. Flow in supply piping might create enough pressure drop to overcome pump head and stop the flow through a return line, but the pump will start the flow again as soon as the faucets are closed.

DOES A TANK BEHAVE LIKE A POND OR A LAKE?

The difference between a pond and a lake is that the water in a pond stays at about the same temperature throughout the pond, while water in a lake arranges itself in layers according to temperature. Which does the water in a hot-water storage tank behave like, a lake or a pond?

Suppose a 40-gal. tank of water is heated to 120 F and someone turns on a shower which uses 3 gpm. Suppose the shower body is mixing the water down to 103 F, and the incoming cold water is 50 F. As the mix temperature is (hot temp times hot fraction) + (cold temp times [1 minus hot fraction]), the hot fraction is ([mix temp minus cold temp] divided by [hot temp minus cold temp]), which in this case is (103 - 50) / (120 - 50), which equals 0.75, or 75 percent of the 3-gpm flow is hot. This means hot water is leaving the tank at 2.25 gpm. So without counting new heat added to the tank, the tank can supply the shower for (40 / 2.25), or 18 min. Or can it?

If the tank behaves like a pond, the water temperature throughout the tank will be dropping while the person is in the shower. As soon as the whole tank is down to 103 F, the person will stop showering and either turn up the aquastat or make a phone call.

If the tank behaves like a lake, there will be a layer of hot water on top of a layer of cold water, and, in theory, the person can use all 40 gal of water for showering before the water suddenly turns cold.

Reality is closer to a lake than a pond. Hot water is lighter than cold water because heat expands the water, causing the same mass of water to take up less space. Conduction and some mixing cause the boundary to be more gradual than sudden. Eighty-percent drawdown is one rule of thumb some people use. In other words, 80 percent of the water stored in a tank can be drawn out of the tank at about the desired temperature. Add to that the amount of water the heat source will heat in a given time and you have the maximum amount of hot water you can get out of the tank in that time.

Therefore, stratification is necessary to good performance of any storage tank or storage water heater. Without stratification, people would stop showering when about 25 percent (120-103)/(120-50) of the heat leaves the tank instead of when about 80 percent of the water leaves the tank. But too much of a good thing is not good either.

Stratification makes it hard to control the temperature of the water leaving the tank. Hot water collects at the top of the tank where the aquastat cannot sense it, because the aquastat is near the bottom of the tank. The aquastat can call for more heat to be added to the tank while the water at the top of the tank is hotter than the aquastat's setpoint. Some people in the water heater industry admit this is a problem, but only with the unusual case of repeated small draws of hot water. However, repeated small draws of hot water can be quite common. For example, several people getting up and washing their hands and preparing breakfast constitutes repeated small draws, which can leave the water overheated for showering. Full showers are a relatively small load in an apartment house, which can overheat the tank for showers that follow. Hoping for an optimal load profile is no solution.

Overheating resulting from stratification is presumably more likely or more noticeable with an indirect water heater or a storage tank than with a direct-fired heater because the chimney is constantly pulling heat out of the tank, reducing some of the overheating.

One water heater manufacturer has responded to the trend of ever increasing firing rates combined with ever smaller tanks by selling a heater with a built in control that circulates water from the top of the heater back to the bottom (piping and pump by others) if the temperature of the water approaches the setpoint of the manual reset aquastat at the top of the tank: 194 F.

Just for fun, I asked a company rep at a trade show if water close to 194 F could ever leave the tank if the aquastat was set at 120 F. He insisted it could not. I then asked if 192-F water could ever be in the top of the tank, and he said it could. So I asked what would prevent the 192 F water from leaving the tank if someone opened a faucet, and he sort of agreed that it was possible for his heater to deliver overheated water.

A pump constantly pumping a lot of water from the top of the tank back to the bottom would solve the problem of delivering overheated water because of stratification, but would create a "pond" problem and severely limit the effective storage capacity. So what is the solution?

FLOW IN THE RETURN LINE

I set up all indirect water heaters and other hot water storage tanks with a return line and a pump running nonstop. The trick is to make the circulation fast enough to stop overheating caused by stratification, but slow enough to avoid the pond problem. How do you calculate the correct circulation rate? I have no idea.

Fortunately, the smallest pumps on the market seem to work just right for a single-family house, while slightly larger pumps work for buildings as large as an indirect water heater can handle. When I say "work" I mean the strict standard that measuring the temperature shows hot water leaving the tank at a steady temperature, not the looser standard of "nobody complained" (Figure 2).

Pumps are available with timers to turn the pumps off at certain times. I don't want the hot water overheated some of the time, even if I can choose which time, so I always wire the pump to run nonstop.

Some pumps have built-in aquastats that turn the pump on and off, depending on the temperature in the return line. I do not use aquastats to turn a return line on and off. I keep the pump running to prevent stratification.

WHAT ABOUT HEAT LOSSES FROM THE PIPING?

This is a major problem. Keeping the hot water supply piping and return piping hot all the time means a lot of heat will escape into the building, or escape outdoors. Pipe chases are full of holes that go from floor to floor, so in the winter they can act like chimneys and leak the heated air into the attic and other places from where it can escape outdoors. Depending on how airtight the building is, some heat will be added to the building in the winter, which is not a loss of heat. In the summer, the chimney effect will be minimal, so more of the heated air will stay in the building, where it can add to the air conditioning bill.

For these reasons, I make sure new systems I design have a minimum of return-line piping and that all the piping is well insulated. Instead of an apartment house having one hot water supply pipe and one return line for each plumbing stack, return lines can come off the top of each upfeed hot water supply pipe and run horizontally at the top of the building and join into one return line. For systems with one hot water supply pipe running horizontally at the top of the building and supplying downfeed hot water supply pipes, the return lines can come off the bottom of each riser and connect with each other from there. In any case, each return line still gets its own check valve. This minimizes the length of the piping, which reduces the amount of heat escaping into the building.

Instead of insulating hot water pipes with ½-in. fiberglass or ⅜-in. foam, I specify much thicker insulation, such as 1-in. fiberglass properly attached so it will not fall off soon. And instead of the silly habit of only insulating the supply pipe and leaving nearby branches naked, I specify insulation on the first 3-ft of each branch off the riser.

This minimizes heat escaping from the hot water supply and return piping, and the branch piping too. Which uses more energy: the heat loss from constant circulation or the heat loss from overheating resulting from stratification? I do not know. It would be very hard to calculate with a computer model because there are too many variables, including structure airtightness and the effect overheated water has on faucets—it can destroy them and cause running leaks of hot water. Should the two energy losses be compared, assuming someone will fix leaks quickly? I prefer the real world over a computer simulated world, so I think turning the pump off, overheating the water, and letting hot water run down the sewer will use more energy than running the pump nonstop in a building with well insulated hot water supply and return piping.

Energy use aside, sending up overheated water is dangerous. Thousands of people get scalded by overheated hot water every year, so that is enough reason for me to favor keeping a return line pump running nonstop. What about buildings that are not piped with a return line?

FAKE RETURN LINES

Preventing too much stratification depends on circulation between the top of the tank and the bottom, not on sending the water all around the building. A “fake” return line that runs from the hot water pipe at the other end of the basement back to the cold inlet to the hot water storage tank can effectively prevent overheating resulting from stratification. Reasons to pipe it back from the end of a supply pipe instead of just from the tank outlet include:

- Reduced flow that results from friction preventing the tank from acting like a pond.
- Some effective hot water storage in the water in the hot water pipe and in the thermal mass of the pipe itself.
- A reduced wait for hot water. The occupants have to wait for the smaller branch pipe to fill with hot water, but do not have to wait for the large common supply piping to fill with hot water.
- In an upfeed system with the risers fed from the bottom, convection can move substantial heat into the risers, so they should be well insulated despite the lack of pumped circulation in them.

RETURN TAPPINGS PARTWAY UP THE TANK

Some storage tanks and indirect water heaters have a tapping where a return line can be connected to the tank somewhat above the bottom of the tank. Presumably, the intent is to avoid mixing the cold water on the bottom of the tank with the hot water at the top of the tank, which would make the tank behave like a pond. I prefer to connect the return line to the cold water pipe just before it enters the bottom of the tank and avoid the pond problem by installing a return pump too small to create a pond problem.

USING COLD WATER PIPE AS A RETURN

In a classic, “I should have thought of that,” move, several manufacturers are selling devices that use the building’s cold water pipe as a return line. One arrangement has the occupant start a pump located under a sink that pumps hot water into the cold pipe instead of having the occupant run water down the drain. Because circulation is not constant, this arrangement will not stop stratification.

Another arrangement uses a temperature-sensitive valve between the hot and cold pipes at a sink far away from the source of hot water. A pump mounted on the outlet of the tank pulls from the cold piping and pushes into the hot piping. When the valve senses cold water, it opens and allows the pump to dump some water from the hot pipe into the cold. When the valve senses hot water it closes. This arrangement causes more flow than the pump triggered by an occupant, but probably not enough to prevent stratification.

There might be a good compromise, which, I caution, I have never tried: One or more of the temperature-sensitive valves that let hot water into the cold water piping could be installed at sinks far from the hot water storage tank, and a pump could be installed near the tank. But a piece of ⅜-in. pipe about 10-ft long could be installed between the hot outlet from the tank (downstream of the pump) and the cold inlet. This way, the constant flow through the ⅜-in. pipe and the tank will prevent stratification while leaving enough pump head to move water through the temperature-sensitive valves under the sink. The heat loss from the piping will be minimal, the cost of a return line will be avoided, and stratification will be prevented.

The piece of ⅜-in. pipe is the less expensive and fiddleproof equivalent to installing a larger pipe and a partly closed valve. People who think the ⅜-in. pipe will clog can ask a plumber how many times a ⅜-in. sink or toilet supply has clogged—not a clog at the inlet to a toilet ballcock, but a clog in the ⅜-in. pipe. Once installed without a valve, nobody can make a mess by opening or closing a valve.

The head loss through the pump at times of peak draw can be avoided by piping a bypass around the pump and installing a check valve on the bypass. When nobody is using water, the pump head holds the check valve closed and is available to move water through the valves under the sinks and through the ⅜-in. pipe. At times of high draw, most of the water will flow through the bypass, taking the pump out of the picture at a time when it is not needed.

CONCLUSION

For making hot water, safety should be the first priority, which means never overheating the hot water. Never overheating cannot apparently be done with an indirect water heater without some constant circulation. Comfort and energy saving are other priorities that can also be enhanced by designing a system that will never overheat domestic hot water.

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